

Closures - Maximizing Benefits, Minimizing Risks

Richard Gibson, Director, Scorpex Wine Services, Australia

Closures for sealing wine bottles have undergone a revolution in the last ten years. There are now more choices for sealing wine bottles than at any other time in the history of the wine industry. The dominant wine bottle closure for centuries, cork, is fighting for market share as wine producers and wine consumers now use and accept many alternatives.

Wine bottle closure performance is a complex field. Closures must perform well in the following areas to satisfy all members of a winery team – procurement staff, bottling staff, QA, winemakers and marketers:

1. **Cost** – closures that are readily available at a consistent, reasonable cost are preferred by procurement staff.
2. **Consistency** – QA staff favor consistent closures that give uniform performance and require minimal pre-use and post-application checks.
3. **Application** – Bottling staff favor closures that go on or into the bottle with minimal adjustments, product loss and labor input.
4. **Wine Impact** – winemakers favor closures that do not modify the color, aroma and flavor of their wines, while allowing development of the wine at a consistent rate.
5. **Consumer Impact** – marketers favor closures that can be decorated well and enhance product appeal to consumers. They also prefer closures that generate a minimum amount of negative consumer feedback over issues such as closure removal and product modification.

The drivers for change in the wine closure market are based on technical, economic and market factors. The consistency of cork's technical performance has been found wanting as the general standard of quality assurance in the world wine industry has grown. The cost structure of cork, based on appearance, has also led to a review of closure choice by many companies as the world wine market place becomes increasingly competitive. Consumer perceptions of closures are very important in determining closure choice.

The concept of technical risk is an important factor in wine bottle closure choice. All closures introduce technical risk. The technical basis of closure performance in key areas must be understood to enable technical risk to be managed effectively.

For example, the ability of cork to pass contaminant molecules with very low aroma thresholds, such as 2,4,6 trichloroanisole (TCA) to wine, represents a large risk to bottled product quality. Some companies

regard this risk as unmanageable – no matter how many procedures are put in place to detect and remove closures containing TCA, contaminated corks will enter the system and tainted product will result if cork closures are used.

If the risk cannot be effectively managed, it must be removed. To avoid the risk of taint, some wine companies have switched to other closures. However, the technical risks of the use of these other closures must also be recognized and effectively managed. If this is not carried out, producers may simply replace an old problems with new problems – problems that can be even more detrimental to product quality than the old ones.

The experiences of the Australian wine industry as it has embraced closure change have exposed a number of the key areas in which risk management focus must be placed to minimize the emergence of new problems. This presentation will highlight some of the areas of technical risk associated with different closures, and discuss ways in which the risk can be managed.

Cork:

The technical risks associated with the use of cork are well documented. The major risks are wine tainting derived from contamination of cork with halogenated anisoles (HAs), such as TCA and TBA, and inconsistent oxygen barrier properties.

As the consistency and quality of wine has increased, the impact of contamination of cork with HAs on bottled wine quality has become more and more exposed. Despite a large amount of work, the traditional process of cork batch assessment by sampling and testing a representative sub-lot for contamination by sensory or instrumental techniques cannot manage the risk of wine taint to the satisfaction of many wine companies.

To manage the risk of cork contamination and wine taint more effectively, one or more of the following processes must be put in place:

1. Prevention of HA transfer to and/or formation in the cork.
2. Removal of HAs from cork
3. Prevention of the transfer of HAs from the cork to the wine.

The sources of contamination of cork by HAs have not been fully elucidated. Work has shown that TCA may be present in cork bark on the tree in the forest. It can be transferred to cork by aerial migration. It may be formed in cork by chemical and microbial reactions associated with washing processes. While steps have been taken by the cork industry to reduce the potential contamination of cork by HAs during processing, the presence of TCA in cork bark on the tree shows that it may never be possible to

completely eliminate HA contamination. Prevention of HA transfer to and/or formation in the cork cannot give full control of the taint issue.

Several techniques have been proposed over the years to remove HA contamination from cork. These have included removal of parts of the cork structure thought to contain HAs, treatment with microwaves, steam distillation and supercritical carbon dioxide extraction. It now appears that TCA can be removed from some forms of cork (especially granulated cork) by some of these techniques. It remains to be seen whether the treatments can be carried out consistently, at reasonable cost and without affecting other aspects of cork function.

A number of encapsulation and barrier techniques to hold HAs in cork and prevent its migration to wine after bottling have been proposed over the years. None has been entirely successful. However, a development in Australia called ProCork looks more promising. The ProCork process involves the application of a multi-layer membrane to each end of the cork. The membrane prevents the transfer of TCA from the cork to the wine.

Inconsistent oxygen barrier performance has also been a significant risk to wine quality when using cork. So called “random oxidation”, manifested by a percentage of grossly oxidized bottles, or bottles affected by aerobic microorganism growth, caused a large amount of product loss in Australia in the late 1990s, especially in stock stored upright. It has been shown that the oxygen transmission of cork is less consistent when bottles are held upright, and that cork-sealed bottles should be held inverted or laid down. While this simply appears to validate a well-known industry maxim, the technical basis of the difference in performance is not clear.

The risks of cork use have led wine companies to use other closures. The two major categories of closure that are also in use are synthetic polymer insertable closures (often referred to as synthetic corks) and screwcaps.

Synthetic Closures:

Synthetic corks are made from expanded polymer foams. They are made by injecting polymers and a foaming agent into a mould (injection moulding), or extruding a polymer and foaming agent mix from a die (extrusion). Issues with transmission of plastic taint have been overcome by the selection of inert polymers, and synthetic closures produced by reputable suppliers do not taint wine. However, the use of synthetics introduces other technical risks that must be appropriately managed.

All currently available synthetic closures allow reasonably rapid oxygen transmission from the external atmosphere to the product. The oxygen permeates through the plastic matrix and gaseous voids in the body of the closure. The rate of oxygen transmission is the same for inverted and laid down bottles.

There are some differences in oxygen transmission rate depending on the polymers used, the density of the closure and the consistency of cell size in the closure construction.

The impact of this elevated oxygen transmission is restricted shelf life. The stock rotation of wine sealed with synthetics must be closely managed. Old stock will simply become oxidized. Long-term maturation of wine under synthetics is a high-risk exercise. While some short-term benefits may be seen in red wine maturation from the increased oxygen exposure, storage in the bottle for too long will simply result in tired, oxidized wines.

Scalping is another risk that must be managed when synthetics are used. This phenomenon involves the adsorption of volatile aroma compounds by polymers. It has been studied extensively in the food industry. Work with wine shows that, in general, synthetics scalp more than cork and screwcaps. The impact of scalping is difficult to manage. However, not all compounds found in wine are scalped, and not all scalped compounds are odor active. Synthetics may not have any impact on the sensory quality of a number of wine styles. However, it is well known in the food industry that polyethylene, used as a base material in many synthetic closures, will adsorb terpenes, the group of compounds responsible for varietal aroma in Riesling and Gewurztraminer wines. Synthetics based on polyethylene should not be used in these wines.

The consumer must be able to get the closure out of the bottle to enjoy the wine. Synthetics have developed a reputation for difficult extraction. The extraction difficulties appear to be caused by two reasons. In an attempt to minimize oxygen transmission, some producers increased the density of their closures by increasing the polymer content. The higher density closures were more difficult to extract. The behavior of surface treatment compounds on a synthetic surface differed from the behavior of the same compounds when applied to cork. It has taken synthetic closure producers some time to determine the right mix of lubricants to ensure that their products can be inserted and extracted with ease.

The pressure in the bottle after insertion of closures such as cork and synthetics is an important issue that must be managed correctly. Cork seems to “vent” pressure differences between the bottle and atmosphere – gas transfer takes place around or through the closure to equilibrate pressure differences, and the closure does not move in the bottle neck. The gas transfer may, however, cause rapid oxidation issues. Synthetics do not vent as readily as cork. Both very high and very low internal bottle pressure should be avoided when using synthetics, as closure movement may occur. High pressures can be generated by the technique of injecting CO₂ into the headspace of the bottle prior to closure insertion. Although the CO₂ will soon dissolve into the wine, the transient high pressure may cause closure movement after insertion. Exposure of bottles to high temperatures can also cause high internal pressures, due to wine expansion.

Very low internal pressures can be generated by the use of excessive vacuum at closure insertion. Only sufficient vacuum should be applied to achieve a pressure equivalent to atmospheric pressure in the bottle after closure insertion. Excessively low pressure can lead to inward movement of synthetics and rapid air entry from the atmosphere to the inside of the bottle with corks, both very undesirable effects.

Screw Caps:

Screwcaps are now very popular in Australia and NZ as a bottle seal for wine. The quality of the screwcap seal depends on characteristics of the cap, bottle and application equipment. All of these factors must be managed to obtain satisfactory results. While the screw cap liner that is popular in Australia and New Zealand is inert and does not contribute or remove aromas, the anaerobic conditions that it generates in the bottle can lead to sensory changes.

There are many different grades of screw cap liner available. Only a small number of these are suitable for use with wine. In Australia and NZ, the tin faced liner is widely used. This liner gives low oxygen transmission and is suitable for long-term bottle storage. Liners that use an aluminum layer are also available, but this metal layer is not as flexible as tin and gives a less consistent seal. Pure polymer liners allow more oxygen transmission. Saran is popular for wines in some countries, such as Switzerland, but shelf life may be limited. Liners made from other polymers are not suitable for use with wine.

To ensure consistent application, the outer cap shells must be made of aluminum alloy with consistent malleability. Variation of shell malleability within a batch may give uneven application, even when application equipment is correctly adjusted.

The quality of the bottle rim sealing surface is critical for screw cap performance. Any flaws can prevent a good seal between the cap and the bottle top. The bottle must also be vertical to ensure that the screw thread is applied completely and evenly around the bottle finish. Bottles with a screw cap finish must be inspected closely by the glassmaker to ensure that faulty bottles are culled.

The application of screw caps must be very carefully managed to ensure that product quality is maintained. Poor application can cause leakage, oxygen entry and difficult cap removal. Screw cappers have a number of adjustments that must be set up to give the right head pressures and roller pressures to ensure a good seal. The quality of cap application can be monitored by measuring the torque required to remove caps.

Use of the BVS glass finish on the bottle and matching cap application heads reduce the risk of post-application damage that can reduce the seal integrity of screw capped bottles.

The tin lined screw cap produces a low oxygen environment in the bottle. This is viewed as beneficial in retaining primary fruit characters and freshness in appropriate styles of wine. However, the anaerobic environment has been shown to facilitate the development of sulfide characters in susceptible wines. It is thought that susceptible wines contain relatively high levels of precursors that have a high aroma threshold. They cannot be detected in the sensory profile of wine, and cannot be removed by copper treatment. After bottling, the low oxygen environment in screw capped bottles allows the accumulation of compounds with a very low aroma threshold from these precursors, and the wine takes on sulfidic notes. It is very difficult to treat wines to remove the precursors prior to bottling, and impossible to predict the likely future behavior of wine in an anaerobic environment. Wine making techniques that reduce the generation of sulfide compounds in general, such as adequate yeast nutrition, appear to be helpful in reducing the propensity of wines to develop reductive notes in bottle.

It should be noted that this effect can also be seen with other closures, such as some corks. However, the production of reduced characters is more consistent and intense when susceptible wines are bottled with screw caps with tin liners.

The nature of the headspace gas in the bottle has also been a matter of some interest. Work has been carried out with using a small amount of air and flushing with inert gas. A cap application machine is now available that is designed to draw a vacuum in the headspace prior to cap application. There is no headspace compression when caps are applied, but vacuum may help reduce the oxygen content of the headspace. The use of increased headspace air content does not seem to have an impact on the onset of reduced characters under screwcap. More oxygen at bottling simply causes more oxidation. The reactions that cause reduced characters seem to be linked to the long-term oxygen transmission effects of the closure, rather than oxygen incorporated into the wine at bottling.

Other new closures are being introduced for wine, such as a glass plug with a polymer gasket and a plastic plug that is pressed into a standard bottle finish. Valid testing of these devices is required to ensure that the technical risks associated with their use are known and understood. From this understanding, evaluation of the technical risks of their use can be made and techniques to manage the technical risk can be introduced. If the risks cannot be effectively managed, the closures provide little or no benefit over current closure options, the cost of the closures is too high or consumers do not accept the closures on bottles of wine, it is unlikely that they will succeed.



CLOSURES

MAXIMIZING BENEFITS, MINIMIZING RISKS

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Scorpex Wine Services
New York Wine Industry Workshop
7 April 2006

CLOSURES FOR WINE:

- There have never been more choices available for wine bottle closures
- Closures have a significant impact on wine style and quality – as perceived by the consumer



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Closure Choice Factors:

Not all choice factors involve product quality.....

2. **Cost** – Procurement/Finance
3. **Consistency** – QA
4. **Application** – Bottling
5. **Consumer Appeal** – Marketing

And then....

1. **Product Quality**

Closure Choice:

- Blend of technical, economic and market factors influences closure choice
- Closures can excel in one area and present considerable risks in others
- Cost, marketing issues – outside the scope of a technical discussion
- ***Understanding and managing technical risks – key closure issue***

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Understanding the Risk Profile:

- Published research
- Internal trials
- QA data
- Customer and consumer feedback
- Supplier review

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Technical Risks - Closures

1. Contamination
2. Taint
3. Oxidation
4. Reduction
5. Leakage
6. Scalping (removal of aroma compounds)
7. Closure movement
8. Ease of removal

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Avoiding Unmanageable Risk:

- Change closure type?
- Technical risk understanding management is critical when closure choice is changed
- New problems may be worse than the old ones.....

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Managing Technical Risk:

Closure:

- Pre-use testing
 - Supplier
 - In-house
- Monitoring
- Specifications

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Managing Technical Risk:

Not just management of the closure.....

- Bottle characteristics
- Closure application
- Wine parameters
- Post-bottling storage conditions

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Technical Risk Profiles:

- Cork
- Insertable synthetic closures
- Screwcaps

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Cork – Major Risks:

- **Taint**
 - Halogenated anisoles – TCA, PCA, TeCA, TBA are the key compounds
 - Formed by mould action on precursor compounds in cork, or in other materials with subsequent transfer to cork
- **Inconsistent oxygen barrier**
 - Permeation, diffusion

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Taint:

Supplier and pre-use QA widely used

- Sampling often limited
- Instrumental and sensory techniques used
- May isolate high taint batches
- Cannot guarantee closure performance

Pre-use testing cannot manage risk to an acceptable level.....

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Management of Taint:

- Prevent TCA formation in cork
- Prevent TCA transfer to cork
- Remove TCA from cork
- Prevent transfer of TCA from cork to wine

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Prevent TCA Formation in Cork:

- Steps taken to reduce incidence of TCA precursors during cork production e.g. mould, chlorine
- However, TCA is present in cork on the trees in the forest.....

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Prevent TCA Transfer to Cork:

- Suppliers have taken steps to prevent TCA transfer to cork from sources such as wooden products and soil
- Every shipping container, cardboard carton and wooden pallet is a potential source of TCA.....

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Remove TCA from Cork:

Promising developments....

- Supercritical CO₂ extraction
- Steam extraction
- If proven, may remove a major technical risk, but.....
- Post-treatment contamination must be avoided

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Prevent Transfer of TCA to Wine:

- Encapsulation techniques tried, not successful
- Problems with thick silicon barriers – TCA transfer during transport

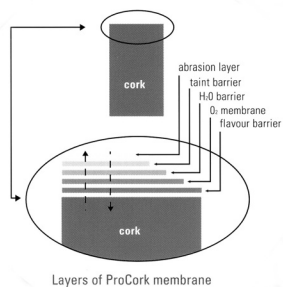


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New Technique – Membrane Barrier:

ProCork:

Multilayer
membrane
barrier applied
to each end of
the cork



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Inconsistent Oxygen Barrier:

- “Random oxidation” in upright stored bottles
- Variation in oxidation status



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Inconsistent Oxygen Barrier:

- Trials showed that cork performance is more consistent with laid down or inverted bottles
- Membrane layer also improves oxygen barrier performance

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Oxygen Permeation or Diffusion?

Permeation:

- Transfer through micro channels or pores
- Driven by **pressure** differential

Diffusion:

- Transfer through the molecular matrix of the closure material
- Driven by **concentration** differential

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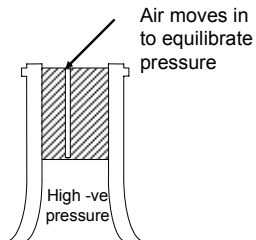
Cork Oxygen Entry:

- Primarily permeation – cork vents
- Exacerbated by pressure differentials between the bottle and the external atmosphere
- Negative bottle pressure causes air entry
- Sources of negative bottle pressure
 - High headspace vacuum at bottling
 - Wine contraction - cooling

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High Headspace Vacuum:

Aim for zero or very slight negative headspace pressure after bottling



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Wine Contraction – Cooling:

- Wine bottled warm – cools and contracts after bottling
- Bottle wine close to likely storage temperature
- Temperature fluctuation during storage
 - Gas exchange can occur if bottles are stored upright

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Synthetics:

- No endemic TCA....but taint is not impossible
 - Acquired TCA
 - Raw materials
- Manufactured product - consistent performance
- **Key Risks:**
 - Oxidation
 - Scalping
 - Closure movement

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Synthetics and Oxidation:

- Oxygen enters by diffusion....same entry rate upright and inverted
- Higher closure density increases oxygen barrier....but may impact extraction force
- Oxygen entry usually consistent within populations of the same closure

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Synthetics and Oxidation:

Solutions:

- Manage bottled product stock age
 - Warehouse
 - Distribution
 - Retailer
 - Consumer
- Manage wine antioxidant levels
 - SO₂
 - Ascorbic acid

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Synthetics and Scalping:

- **Scalping** – removal of aroma compounds from foods and beverages by packaging materials
- AWRI research shows that synthetics scalp some wine aroma compounds
- Limited impact in some styles:
 - Compounds not present or present well below aroma threshold
 - Compounds present in considerable excess of aroma threshold

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Scalping:

- Terpenes – main aroma compounds in Riesling, Gewurz, Muscat
- Food industry literature – terpenes are adsorbed by polyethylene
- Polyethylene based synthetics should not be used with Riesling.....

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Synthetics and Movement:

- Synthetics do not vent
- Large pressure differential between the bottle and the atmosphere may cause closure movement
- Negative bottle pressure – closures move in
- Positive bottle pressure – closures move out

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Synthetics and Movement:

- Headspace pressure critical – neutral
- Temperature change during distribution must be avoided
- Allow sufficient headspace to allow gas compression if liquid volume change occurs

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Screwcaps:

- Now the standard closure for white wine in Australia and NZ
- Technical performance is good – no taint, no scalping
- However, risks can occur and must be managed
 - Oxidation
 - Reduction.....



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Screwcaps and Oxidation:

- Screw cap liner determines oxygen barrier characteristics
- High barrier liner is used in Aust/NZ
- Tin layer prevents oxygen entry



- Other liners allow more oxygen entry and may not be suited for long term use

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Screwcaps and Oxidation:

Liner Material	cc oxygen/m ² /day
Polyethylene	5000 - 10000
PET	100 - 200
PVDC (Saran)	10 - 60
Tin	< 10

Liner Type:	PE	PVC	PVDC	FOIL
Oxtrans:	0.09	0.004	0.001	0.0002
(cc/closure/day)				

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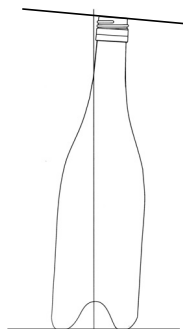
Screwcap Application:

- Good application is essential for avoiding oxidation with screw caps
- Good application requires:
 - Good bottles
 - Well maintained and adjusted capping equipment
 - Consistent caps

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Glass Quality:

- Quality of sealing surface – flat, with no splits, barbs, channels or cracks
- Quality of thread moulding
- Sealing plane must be horizontal

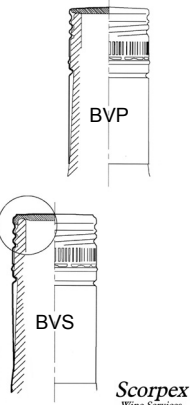


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BVS Bottle Finish:

- BVS bottle finish and matching capping head should be used
- Rolled edge helps to prevent post-bottling impact damage to seal
- Bague Verre Stelvin

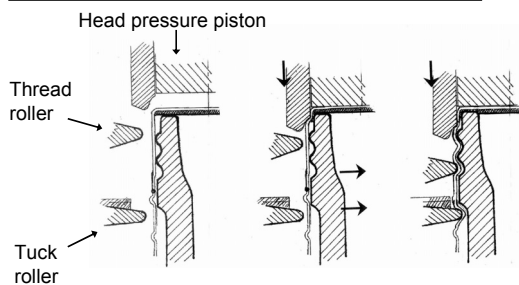


Capping Equipment:

- Cap application is carried out in a three stage process
 - Head pressure
 - Rollers – thread, tuck
 - Release of head pressure
- Head pressure and roller springs must be adjusted to correct specification

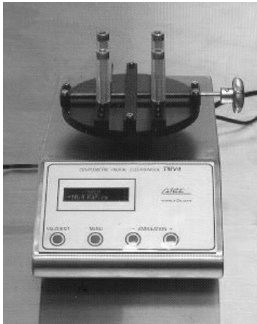
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Capping Head:



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Capping Equipment:



- Monitor capper performance by testing torque to turn the cap on sealed bottles

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Cap Consistency:

- If the malleability of the metal shell varies within cap batches, problems may occur.
- Cap consistency depends on raw material quality and manufacturing processes
- Some suppliers are more consistent than others.....

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Post - Bottling Reduction:

- Results from published trials show the development of **sulfide like odours** (SLOs) in wine in bottles sealed with low oxtans closures
- Same wine in bottles sealed with closures with higher oxtans do not develop SLOs

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Reduction in Bottle:

In several of these trials, the low oxtrans closure is a screw cap with a foil lined wad

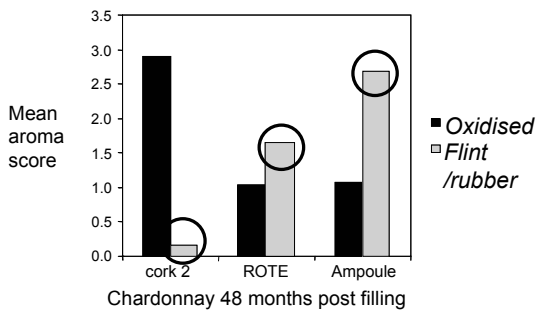
In the other trials, the closures used to create a low oxygen environment are:

- Bark cork with a sealing compound applied to prevent gas exchange*.
- Fused glass (AWRI ampoule trial)

* Pers. Comm. Catherine Chassagnou, Agriculture Gironde. See www.bordeauxprof.com/St/Secure/Technique/Donnees/recherche/CA33_bouchons_synthetiques.pdf

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AWRI Ampoule Trial:



Source: Godden et al 2004

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Closure Trial – Zork:

- Semillon wine bottled under Screw cap and Zork



Months	1	3	5	12	18
Oxidized	-	-	-	**Z	***Z
Flint/rubber	-	-	*S	**S	***S

* Low significance ** moderate significance *** high significance

Zork oxtrans: 0.0078 cc/closure/day

Screw cap oxtrans: 0.0005 cc/day/closure

Source: <http://www.zork.com.au/pdfs/18MonthTestResults.pdf>

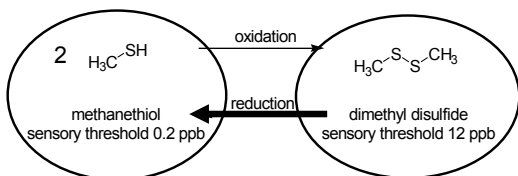
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Current Theory:

- Precursors are present in wine from yeast metabolism during fermentation - disulfides
- Precursors cannot be removed by copper treatment or permanently changed by oxidation
- Low impact precursors can change to compounds with higher sensory impact e.g. thiols
- Equilibrium between low impact and high impact form depends on access to oxygen

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Sulfide Compound Equilibrium:



High impact sulfide

Low impact precursor

Clean wines may form sulfides in bottle.....

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Equilibrium Balance:

The diagram shows two parallel lines sloping downwards from left to right. The top line is labeled "SLOs" at its left end and "Precursors" at its right end. Below this line, the text "Low redox potential, low oxygen, reducing conditions" is written. The bottom line is also labeled "SLOs" at its left end and "Precursors" at its right end. Above this line, the text "High redox potential, high oxygen, oxidative conditions" is written.

Low redox potential,
low oxygen, reducing
conditions

Precursors

High redox potential,
high oxygen,
oxidative conditions

SLOs

Source: Vince O'Brien Winetech 2005

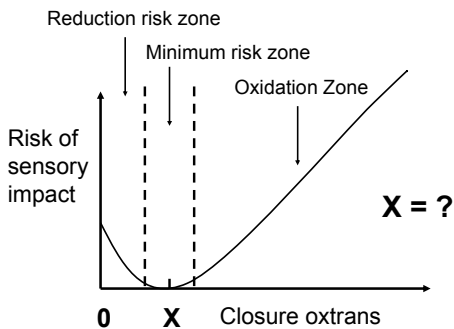
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Managing Reductive Risk:

- Manage the concentration of precursors
 - limit production, remove from wine
- Manage the concentration of high impact compounds once formed
 - residual copper at bottling
- Manage the redox potential of the bottle environment
 - closure choice

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Optimum Closure Oxtans:



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Closure Risks:

- Know and understand the basis of closure performance
- Understand closure strengths and limitations
- Manage risk by managing factors such as:
 - Wine
 - Closure application
 - Post bottling conditions

As well as the closure.....

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